THE FRENULUM OF MOTHS[1,2]

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ABSTRACT: The frenulum of most female moths is a cluster of very large acanthae, commonly 3 in number. The frenulum of the male is a multicellular bristle formed by the adhesion or partial fusion of a group of several dozen acanthae. New is the finding that acanthae can combine into a multicellular bristle of unique structure.

Recently, in sorting my large reprint collection, I came upon an old report that appears to have been missed by Zoological Record and other bibliographic sources. In this, Marshall (1922) described the development of the frenulum, a large bristle or hook at the base of the anterior margin of the metathoracic wings of most moths. It serves to hold the wings together to act in unison in flight. First described by DeGeer in 1752, it has been mentioned by numerous entomologists but Marshall's study is the only significant one.

On the basis of stained serial sections of pupal wings of *Galleria mellonella* L. examined by light microscopy, Marshall (1922) reported that the frenulum of males is formed from protuberances of a group of a dozen or somewhat more cells which become joined together into a single large bristle, but that the frenulum of the female is formed from 2 or 3 larger cells which are spaced a little apart from one another. The result is that the male has a single compound bristle whereas the female has several simple bristles of the sort we have recently termed acanthae (Richards and Richards 1969, 1979). Why this sexual difference exists is not known but it is widely recognized by moth taxonomists that one can readily determine the sex of any individual of most moth families by examination of the frenulum. Additionally, Marshall noticed that the number of units in the frenulum of females was not constant in *G. mellonella*. He examined 897 females. Of these, 456 (51 %) had 3 bristles on each wing, 319 (36 %) had 2 on one wing and 3 on the other, 121 (13 %) had 2 on each wing, and a single female had only 1 bristle on each wing.

I have reexamined the situation with ordinary light microscopy, polarized light microscopy and electron microscopy. There is no trace of a socket or of innervation. Therefore these are acanthae with the frenulum of

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males being unusual in that a dozen or several dozen cells combine to produce a single bristle which reveals its multicellular origin by incompleteness of the fusion (Figs. 1, 4, 5). The difference between males and females, then, is in the number of cells involved, the size of the trichogen cells, and the crowding together of these trichogens. The eventual formation of 1 vs several bristles is secondary to the development differences.

The size of the frenulum is fairly well correlated to wing size within a family but not so well between families (relatively small, for instance, in sphingids). In *Galleria mellonella* the frenulum is about 2 mm long in both sexes but is 0.12 mm in basal diameter in the male in contrast to 0.05 mm in the female. In various microlepidoptera the frenulum can be less than 1 mm long. In large noctuid moths such as *Erebus odora* L. and *Thysania zenobia* Cramer I have measured lengths of 6-8 mm (0.25 mm diameter at base). In the occasional oversized specimens of *T. zenobia* (wing expanse about 30 cm) I would expect a length of 1 cm or slightly more. This is longer than any ordinary seta I have seen in insects but is approached by some hair pencils (which are modified setae). It is about the same length as some of the setae of giant tarantulas.

Cross sections of male frenula cut on an ultratome with a diamond knife show that there may be several dozen units in the noctuid moth *Cirphis unipuncta* Haw. (Fig. 4) but about double this number in the larger *Catocala amatrix* Hbn. (Fig. 5). Also the units in *C. unipuncta* fit snugly together and the cuticles seem to have fused whereas in *C. amatrix* intecellular or interacanthal spaces are common and the cuticles of individual acanthae commonly seem distinct though adherent.

In the females of various moths the details vary. I have seen examples ranging from 1 to 6 bristles. Single bristles are recorded for many Aegeriidae, some Pyralidae, some Pterophoridae and a few others. The ones I have examined microscopically *(Podosesia syringae* Harris, *Melittia cucurbitae* Harris, and *Cissuvora ampelopsis* Engle., all aegeriids) clearly showed the single bristles as multiple acanthae. That means it is identical to that of the male. There is no sexual differentiation in these cases. Three bristles seems to be the commonest number for female moths. I have seen only one case with 6 bristles; this was in the aegeriid moth *Aegeria apiformis* Clerck.

The separate bristles in the female are usually similar but not necessarily so. In the noctuid moth *Cirphis unipuncta* there are 2 large bristles and a third (basal) one that is shorter and much more slender.

After treatment with hot alkali frenula of both sexes give positive chitosan tests. They may or may not collapse depending on how sturdy the procuticular component is. Rather surprisingly, male frenula treated with alkali do not separate into the several dozen units from which they originate.

Fig. 1. Whole mount of the basal half of a fremulum from a male of *Galleria mellonella.* The linear striations are due to the walls of acanthal units. Fig. 2. Part of the tangle of threads resulting from teasing with fine needles a frenulum from a male of *G. mellonella.* Fig. 3. Whole mount of a frenulum of a female of *G. mellonella* after teasing with needles. Fig. 4. Cross section of a frenulum from a male of *cirphis unipunta* (cleaned with hot 4% NaOH, then stained with aqueous OsO_4 before embedding in Durcupan). Fig. 5. Cross section of about half of the frenulum from a male of *Catocale amatrix* [converted to chitosan with conc. KOH at 160°, then stained with aqueous OsO_4 before embedding.]. Fig. 6. Lighter print from same negative as preceding; to show distinctness of acantal cuticles at some places.

Since the trichogen cells do not fuse, each secretes a cuticle (Figs. 4-5) which one would expect to have an alkali-soluble epicuticle on its outer surface. Treatment with hot alkali (KOH or NaOH) should remove an epicuticle. Either the epicuticle is not the cement holding these units together or a secondary adhesion develops as an artifact of the treatment The cross sections suggest that the procuticular walls of the units are fused.

If one teases a male frenulum with sharp needles (with or without pretreatment with alkali) it is easy to fray it into a mass of threads some of which may be acantal units but some of which are so slender they must be from a wall of an individual acantha (Fig. 2). This indicates a linear arrangement of chain molecules within the acanathal wall. A linear arrangement is also implied by the appearance in polarized light. The acanthae of the female frenulum may also be split but not into such a mass of fine threads (Fig. 3).

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